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Influence of land cover on riverine dissolved organic carbon concentrations and export in the Three Rivers Headwater Region of the Qinghai-Tibetan Plateau

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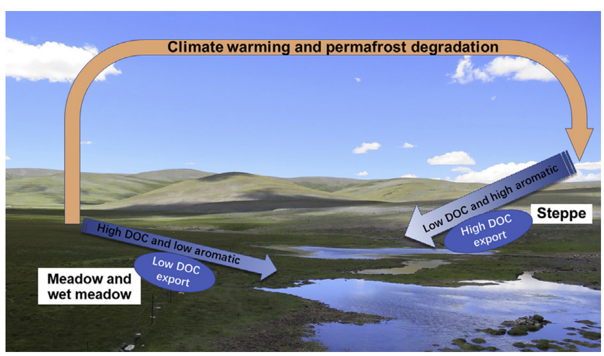
HIGHLIGHTS

- The riverine dissolved organic carbon on the Qinghai-Tibetan Plateau was examined.
- Land cover type (i.e., meadow or steppe) controls DOC concentrations and exports.
- Permafrost degradation may increase riverine organic carbon transport.

GRAPHICAL ABSTRACT



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ABSTRACT

The Qinghai-Tibetan plateau (QTP) stores a large amount of soil organic carbon and is the headwater region for several large rivers in Asia. Therefore, it is important to understand the influence of environmental factors on river water quality and the dissolved organic carbon (DOC) export in this region. We examined the water physico-chemical characteristics, DOC concentrations and export rates of 7 rivers under typical land cover types in the Three Rivers Headwater Region during August 2016. The results showed that the highest DOC concentrations were recorded in the rivers within the catchment of alpine wet meadow and meadow. These same rivers had the lowest total suspended solids (TSS) concentrations. The rivers within steppe and desert had the lowest DOC concentrations and highest TSS concentrations. The discharge rates and catchment areas were negatively correlated with DOC concentrations. The $SUVA_{254}$ values were significantly negatively correlated with DOC concentrations. The results suggest that the vegetation degradation, which may represent permafrost degradation, can lead to a decrease in DOC concentration, but increasing DOC export and soil erosion. In addition,

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Climate change
Riverine transport

some of the exported DOC will rapidly decompose in the river, and therefore affect the regional carbon cycle, as well as the water quality in the source water of many large Asian rivers.

1. Introduction

Dissolved organic carbon (DOC) transport by rivers has been recognized as an important component of the global carbon cycling (Raymond and Bauer, 2001). Rivers receive approximately 2.9 Pg C from terrestrial ecosystems annually of which 0.6 Pg C is buried, 1.4 Pg C is released as greenhouse gases into the atmosphere, and 0.9 Pg C is transported to oceans (Cole et al., 2007; Tranvik et al., 2009). Under global warming scenarios, the riverine transport of carbon in permafrost regions may play a vital role in the carbon cycle and global change feedbacks since permafrost regions store a large quantity of carbon (Hugelius et al., 2014; Mu et al., 2015; Schuur et al., 2015).

The Qinghai-Tibetan Plateau (QTP) is a middle-low latitude permafrost region with a permafrost area of 1.06×10^6 km^2 (Qin et al., 2016; Zou et al., 2017). Similar to the circum-Arctic regions, the permafrost region on the QTP has high soil organic carbon (SOC) content, and stores about 28 Pg C in the upper 2 m of soil (Mu et al., 2015). The QTP is the head water region for several large rivers in Asia including the Yangtze River, the Yellow River, and the Lancang-Mekong River, and the area is known as the Three-Rivers Headwater Region. These rivers are important sources of drinking water to billions of people in Asia and, as such, water quality is very important.

Water quality parameters and carbon transport can be affected by many factors such as temperature, precipitation, topography, weathering and soil erosion, and land cover types (O'Donnell et al., 2012a; O'Donnell et al., 2016). Although the process is complicated (Fig. 1), the relationship between the water chemistry, DOC export and its relationship to land cover types is extremely useful because land cover types are easily accessible via satellite images. Based on the fact that SOC contents are closely associated with land cover types (Wu et al., 2017), we hypothesized that the land cover type controls the DOC and total suspended solids (TSS) concentrations in the river water. Furthermore, since DOC in the rivers of permafrost regions can experience rapid decomposition, we hypothesized that the DOC in large rivers is more degraded than other rivers, which can be demonstrated by the concentration-normalized UV absorbance at 254 nm ($SUVA_{254}$). We also hypothesized that the basic water quality parameters including riverine DOC concentration, pH, turbidity, and TSS concentration are closely associated with one another. To test these hypotheses, we collected water samples from rivers with different types of land cover within the river's catchment area, and examined the relationship between DOC concentrations and exports rates, and water parameters in the eastern QTP.

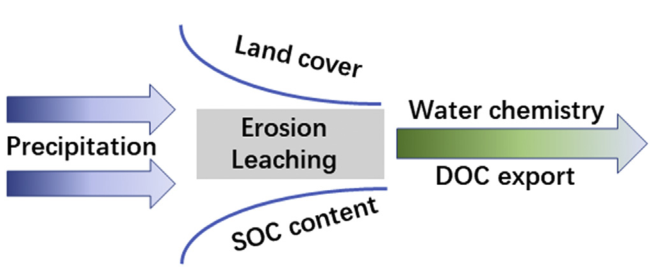

Fig. 1. Conceptual diagram for the river chemistry and DOC (dissolved organic carbon) export.

2. Materials and methods

2.1. Area description

The study areas are located in the Three Rivers (i.e., Lancang-Mekong River, Yangtze River, and Yellow River) Headwater Region, which is the largest National Natural Reserve in China, covering an area of 36.3×10^4 km^2. The study area is within the continuous permafrost zone on the QTP (Fig. 2). The mean annual precipitation varied considerably over the reserve, and about 80% of the annual precipitation falls during the summer, with the highest precipitation occurring in August (Yi et al., 2013). There are few reports of soil taxonomy on the QTP, and the soil orders are largely Gelisols, Aridisols, Entisols and Inceptisols (Li et al., 2015; Wu et al., 2016a). Although the mountainous areas have great heterogeneities in environmental factors such as soil texture, soil parent materials, and topographic conditions, there are four typical land cover types in this area (i.e., alpine wet meadow, alpine meadow, alpine steppe, and alpine desert) (Wang et al., 2016). According to the distribution of land cover types, we selected 7 rivers (Fig. 2) to investigate the riverine DOC concentrations and export rates under different land cover types within the permafrost region. The geographical coordinates and environmental factors for these rivers were summarized in Table 1.

The catchment boundaries were delineated with the hydrologic tools in ArcGIS 10.4, based on the data of ASTER Global Digital Elevation Model (ASTER GDEM). The areas of land cover and permafrost distribution were also extracted using ArcGIS 10.4 from the literature (Wang et al., 2016; Zou et al., 2017).

2.2. Sampling and analysis

Since the maximum precipitation in this area occurs in August, the field work was conducted from August 10 to August 20, 2016. River flows are dynamic properties since they change along with precipitation. Therefore, to avoid possible effects of heavy rainfall, we collected water samples after there had been no storm events during the previous three days. The water quality parameters, including water temperature, turbidity, dissolved oxygen content, conductivity, and pH were recorded at a water depth of 30 cm using multi-parameter water quality sonde (YSI 6600 V2, Yellow Spring Instruments, USA). The water samples (3 L for each) were also collected at a depth of 30 cm and filled into the pre-acidified polyethylene bottles. The samples were kept in a dark refrigerator at 4 °C during transport to the laboratory. The DOC and $SUVA_{254}$ were measured within 1 week of collection.

Water flow in the large rivers (YMR, HLH, XSH and WQ) was measured with a stream Pro ADCP (2.0 M Hz, Teledyne RD Instruments, Poway, CA, USA) during sample collection. For the three small streams (ZD1, ZD2, and FHS), flow transects with uniform depth were selected, and then the flow rates were measured using a Flowtracker (San Diego, CA, USA).

For the laboratory analysis, water samples were filtered through weighted, pre-ashed 0.45 μm glass fiber filters (450 °C for 4 h). The DOC concentrations were measured using a Vario EL elemental analyzer (Elementar, Hanau, Germany), and the glass fiber filters were oven-dried and weighted to calculate the concentration of TSS. The absorbance of water samples at 254 nm were analyzed with a UV-160A spectrophotometer (Shimadzu, Tokyo, Japan) in 1 cm quartz cuvettes. Using absorbance and concentration values, we calculated the concentration-normalized UV absorbance at 254 nm ($SUVA_{254}$), which is a

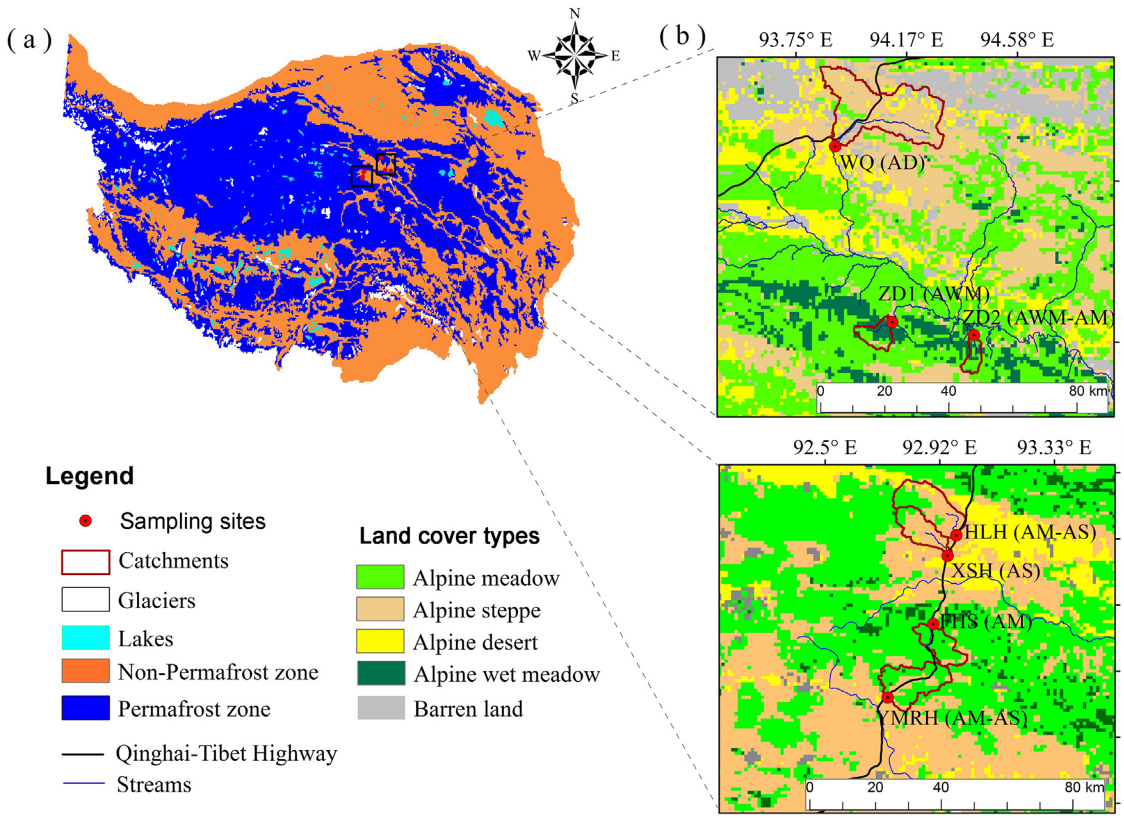

Fig. 2. Permafrost zone on the Qinghai-Tibetan Plateau (a); sampling rivers and the catchments (b).

photometric measure of DOC aromaticity (Weishaar et al., 2003). All of the analyses were conducted in triplicate.

2.3. Data analysis

The DOC export rate was calculated as an area normalized rate:

$$Export\ rate = Discharge \times DOC\ concentration/(Catchment\ area)$$

The export rate was expressed as $kg\,C \cdot km^{-2} \cdot d^{-1}$, and we assume that the discharge and DOC concentrations were constant for an entire day.

We used simple linear regression to quantify the relationship of $SUVA_{254}$ and water parameters. We standardized predictors (mean = 0, SD = 1) to allow interpretation of coefficients as effects for the multiple linear regressions, and all significant models were compared based on corrected Akaike information criterion (Bates et al., 2013; Kuznetsova et al., 2014). Analyses were performed in the lme4 and piecewiseSEM packages (Bates et al., 2013). All the data analyses were performed in R.3.3.3 (http://www.r-projec.org).

3. Results

3.1. Discharge, water quality parameters and DOC concentrations

The XSH river had the highest water flow ($8.1\ m^3 \cdot s^{-1}$), and the ZD1 and ZD2 rivers had water flows of about $0.1\ m^3 \cdot s^{-1}$. Water quality parameters varied greatly among the rivers (Fig. 3). The highest pH value (8.87) was recorded in the XSH river, which had alpine steppe land cover. The lowest pH value (8.24) was recorded in the catchment under alpine wet meadow land cover (ZD1) (Fig. 4a). Conductivity ranged from 0.535 to 10.98 $mS \cdot cm^{-1}$ with the lower values in WQ, ZD1, and ZD2 rivers. Conductivity in FHS, XSH, and YMR rivers varied from 1.86 to 3.07 $mS \cdot cm^{-1}$. The HLH river had the highest conductivity (Fig. 4b). The turbidity and TSS showed similar patterns in the rivers (i.e., the lowest values in the rivers under catchment of alpine wet meadow and alpine meadow, while the highest values in the catchments within alpine steppe) (Fig. 4c and d).

The average DOC concentration in the rivers was $3.95 \pm 1.48\ mg \cdot L^{-1}$, and the median value was 4.15 $mg \cdot L^{-1}$ (Fig. 4e). DOC concentrations showed a clear pattern with the land cover type. The highest DOC concentration was recorded in ZD1 and ZD2 rivers with the land cover types of wet meadow and meadow, followed by FHS, HLH, and YMR

Table 1
The geographical coordinates and environmental factors for the selected rivers.

River	Latitude (°)	Longitude (°)	Elevation (m)	Catchment area (km^2)	Land cover types	BL (%)	AWM (%)	AM (%)	AS (%)	AD (%)	Permafrost (%)
ZD1	N 94.12	E 35.05	4501	74.3	ASM	0	53	41	6	0	80
ZD2	N 94.42	E 35.02	4368	46.4	ASM-AM	0	31	65	4	0	43
FHS	N 92.9	E 34.78	4682	104.8	AM	0	1	86	13	1	90
YMR	N 92.75	E 34.59	4683	193.2	AM-AS	0	1	68	30	1	100
HLH	N 92.98	E 35.00	4580	194.9	AM-AS	1	0	31	64	5	100
XSH	N 92.95	E 34.94	4552	118.2	AS	0	0	19	76	5	47
WQ	N 93.90	E 35.50	4522	559.8	AS-AD	16	0	4	68	11	86

BL, barren land; AWM, alpine wet meadow; AM, alpine meadow; AS, Alpine steppe, AD, Alpine desert.

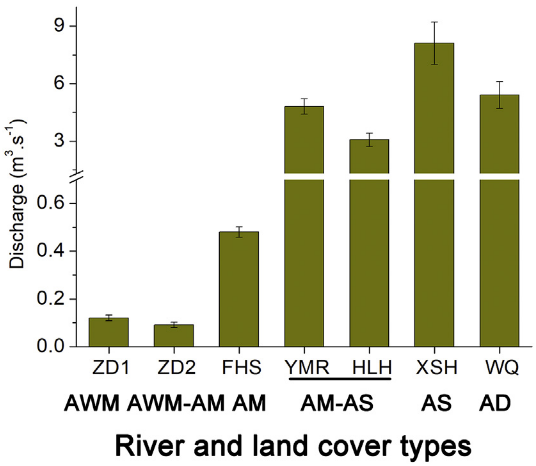

Fig. 3. Water discharge for rivers under different land cover types. AWM = alpine wet meadow, AM = Alpine meadow, AS = Alpine steppe, AD = Alpine desert. Error bars are the standard deviations ($n = 3$).

rivers, which were under alpine meadow and alpine steppe land cover. The rivers in the catchments of alpine steppe and alpine desert showed the lowest DOC concentrations with 2.28 and 1.51 mg·L^{-1} for XSH and WQ, respectively (Fig. 4f). The $SUVA_{254}$ showed the opposite trend with DOC concentration (i.e., the lowest values were recorded in the rivers under alpine wet meadow and alpine meadow, while the highest values were recorded in the rivers of alpine steppe and alpine desert).

3.2. Correlation among water quality parameters and DOC

DOC concentrations were negatively correlated with the $SUVA_{254}$, discharge rates, turbidity and pH. $SUVA_{254}$ was significantly correlated with discharge, turbidity, and pH. In addition, discharge was significantly correlated with turbidity and pH values (Table 2).

DOC concentrations were significantly correlated with the distribution of land cover types in the catchments. The percent of wet meadow and meadow was strongly correlated with DOC concentration, explaining 80% of the total DOC variances (Fig. 5a). The catchments with the higher percent of alpine steppe and alpine desert had much lower DOC concentrations (Fig. 5c and d).

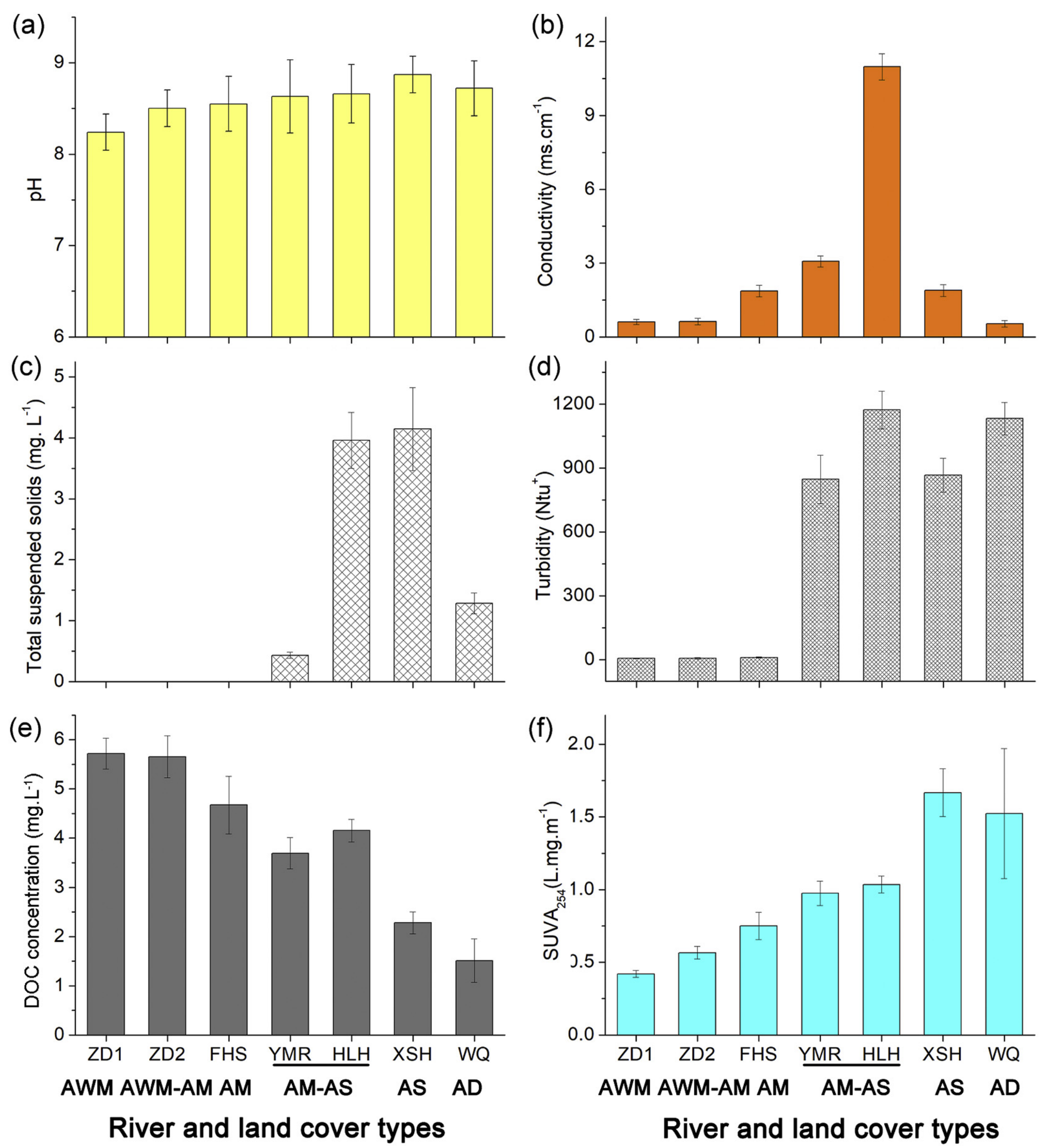

Fig. 4. Water quality parameters, DOC (dissolved organic carbon) concentration and $SUVA_{254}$ (concentration-normalized UV absorbance at 254 nm) values of river water under different land cover types. Error bars are the standard deviations (n = 3).

Table 2
Pearson's correlation coefficients among dissolved organic carbon and water variables.

	DOC	$SUVA_{254}$	Discharge	Turbidity	TSS	Conductivity	pH	DO	Temperature
DOC	1.000								
$SUVA_{254}$	−0.961**	1.000							
Discharge	−0.894**	0.940**	1.000						
Turbidity	−0.795*	0.795*	0.792*	1.000					
TSS	−0.523	0.703	0.683	0.715	1.000				
Conductivity	0.011	0.093	0.086	0.528	0.619	1.000			
pH	−0.834*	0.921**	0.864*	0.741	0.708	0.234	1.000		
DO	0.322	−0.474	−0.445	−0.437	−0.808*	−0.322	−0.307	1.000	
Temperature	0.135	0.110	0.014	−0.170	0.467	0.105	0.251	−0.503	1.000

DOC, dissolved organic carbon concentration; TSS, total suspended solids; DO, dissolved oxygen content.
* $p < 0.05$.
** $p < 0.01$, two-tailed, $n = 7$.

River discharge significantly affected the DOC concentration and $SUVA_{254}$ value. Lower DOC concentrations and higher $SUVA_{254}$ values were expected along with increasing discharges (Fig. 6). The catchment area was significantly negatively correlated with DOC concentrations (Fig. 6), but there was no significant linear relationship between catchment area and $SUVA_{254}$ value.

3.3. DOC export in the catchments

Based on the DOC concentrations, discharge rates and the catchment areas, we calculated the DOC export rates. The DOC export rates in the rivers ranged from 0.80 to 13.45 kg C km^{-2} d^{-1}. The highest DOC export rate was recorded in the XSH river, followed by YMR and HLH rivers. (Fig. 7a). The DOC export rate was significantly correlated with discharge rates (Pearson's $R^2 = 0.805$, $p = 0.03$), while DOC export rate had no significant relationship with other variables. The proportion of the explained total variances in DOC export rate was 57.8% when using the discharge as the predictor (Fig. 7b).

The multiple regressions for DOC concentrations using the distribution of meadow and wet meadow, discharge, catchment area and DOC export rate showed that the main factors affecting DOC concentration are discharge and catchment area, which both had negative effects. The models for $SUVA_{254}$ values showed that the discharge was a positive contributing factor, while the meadow and wet meadow was also a strong predictor, which was negatively correlated with $SUVA_{254}$ value (Table 3).

4. Discussion

The DOC transport and river water chemistry in the permafrost regions on the QTP has not been previously reported although the rivers are important in terms of water resources, as well as the regional and global carbon cycle (Huang et al., 2009; Zhang et al., 2013a; Zhang et

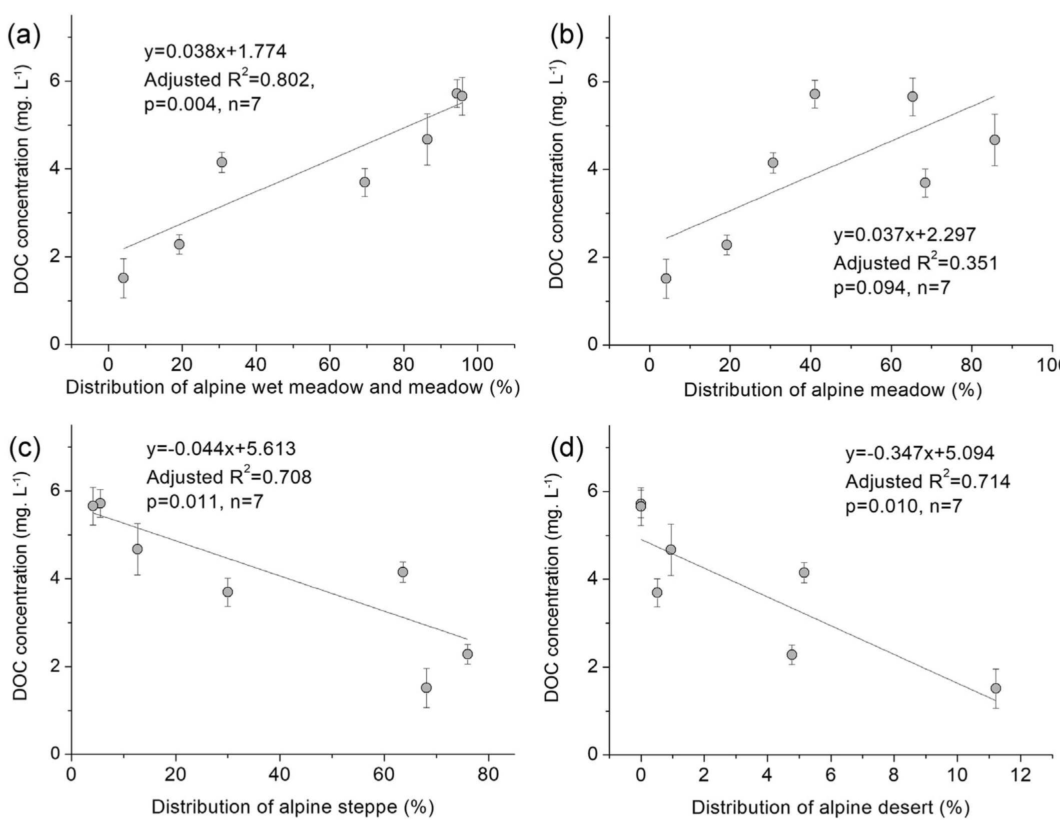

Fig. 5. Relationships between land cover distribution and DOC (dissolved organic carbon) concentration.

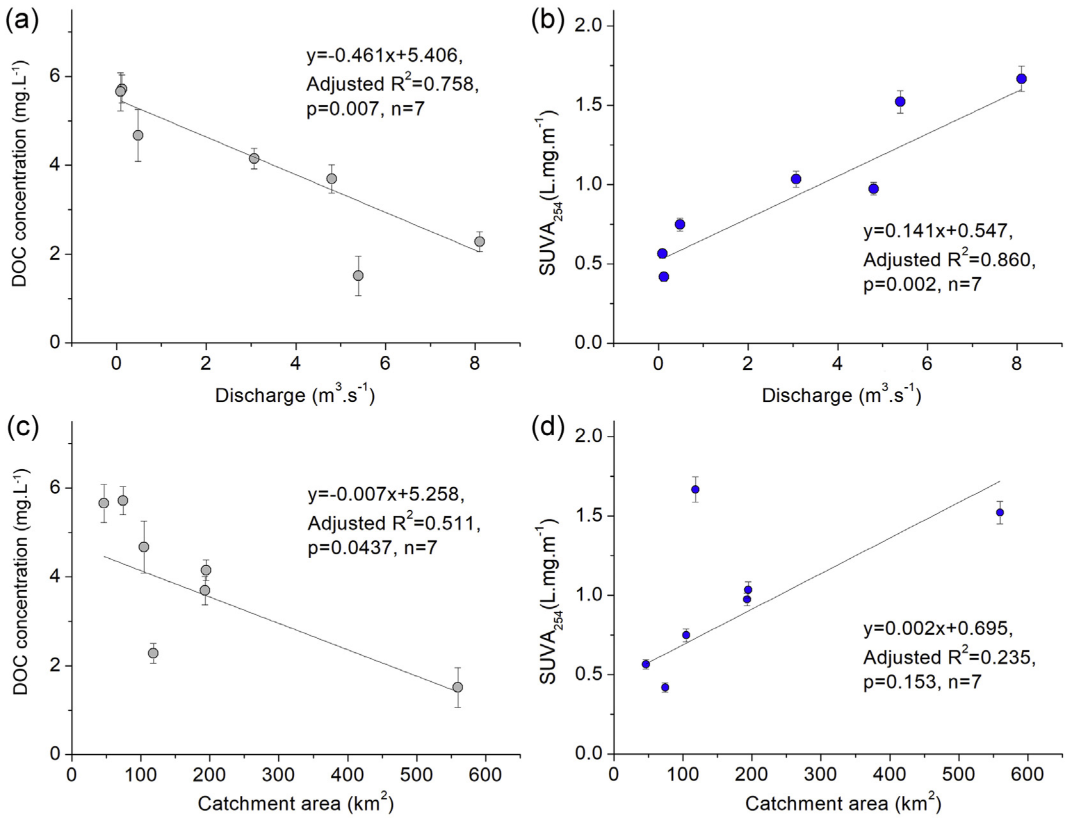

Fig. 6. Linear regressions for DOC (dissolved organic carbon) and $SUVA_{254}$ (concentration-normalized UV absorbance at 254 nm) using discharge (a, b) and catchment area (c, d) as predictors. Error bars are the standard deviations (n = 3).

al., 2013b). Most areas on the QTP belong to semi-arid and semi-humid alpine climate (Yi et al., 2013). Due to the strong evaporation and weathering processes, most soils in the QTP have high salinity and pH values (Wu et al., 2016b; Wu et al., 2017). This likely explains the high conductivity and pH values in the rivers. The pH showed lowest values in the river within alpine wet meadow while highest values was in alpine steppe and alpine desert. This is reasonable since the soils under wet meadow and meadow have higher soil water content and thus lower pH values (Hu et al., 2014). Under natural conditions, the monovalence and divalent cations (such as Na^+, Ca^{2+}, Mg^{2+}) are easily leached from soils and enter the rivers, which further increases pH values in rivers (Jarvie et al., 1997). Therefore, the pH values in rivers may be not ecologically relevant. In our study, all pH values were >8.0, suggesting that the pH values in river are ecologically relevant. This could be explained by the great differences in the soil properties under the four land cover types, which overwhelmed the effects of cations leached from the soils. The cold water temperature of the QTP rivers (Table 1) severely limits phytoplankton production and there were essentially no phytoplankton present in the permafrost region rivers (Chl *a* measured by the YSI6600V2 in our study were always below detection, data not shown). Therefore, it could be inferred that the source of TSS was the soil particles originating from soil erosion within the catchment. The TSS and turbidity values were high in the rivers of steppe and desert, which is consistent with the findings that poor vegetation cover usually results in high soil erosion rates (Zuazo, 2008; Mohammad and Adam, 2010).

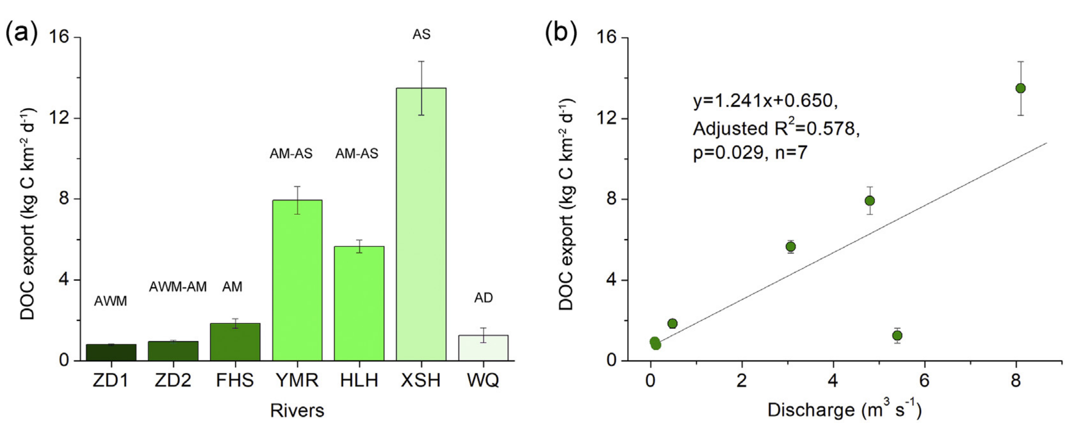

Fig. 7. Distribution of DOC (dissolved organic carbon) export rate in different catchment and linear regression with discharge. Error bars are the standard deviations ($n = 3$).

Table 3
The multiple linear regression models for DOC concentration and $SUVA_{254}$ values.

		Coefficients				Statistic			
		Meadow and wet meadow	Discharge	Area	Export	F	R^2	AICc	p
DOC	Initial	0.121	−0.921	−0.220	0.285	14.04	0.897	−14.67	0.068
	Final		−0.684	−0.455		50.22	0.943	−17.91	0.001
$SUVA_{254}$	Initial	−0.524	0.980	−0.287	−0.425	12.89	0.888	−14.09	0.073
	Final	−0.486	0.538			44.68	0.936	−17.13	0.002

DOC, dissolved organic carbon ($mg \cdot L^{-1}$), $SUVA_{254}$, concentration-normalized UV absorbance at 254 nm ($L \cdot mg \cdot m^{-1}$).

In boreal and Arctic regions, the DOC concentrations vary from <1 mg L^{-1} in glacial streams to over 60 mg L^{-1} in lowland peaty rivers (O'Donnell et al., 2012b; Olefeldt et al., 2014). It has been shown that the DOC concentrations in rivers of permafrost regions depend on many factors such as vegetation, soil parent materials, water flow paths, and even sampling season (Guo et al., 2007; Abbott et al., 2015; Vonk et al., 2015; O'Donnell et al., 2016). Therefore, it is difficult to directly compare our results with those in circum-arctic regions, although a meta-data analysis may disentangle the multiple factors affecting the DOC concentration and thus make it possible to compare our study with those in circum-arctic regions.

The DOC transport involved many processes including DOC production, consumption, adsorption and desorption, and depletion due to flushing during precipitation events (Neff and Asner, 2001). Soil variables such as texture and metal content can influence the stabilization of organic carbon (Mu et al., 2016). Environmental factors within a watershed such as soil and vegetation have strong effects on the water chemistry, and soil type, drainage class, parent material and vegetation type can be used as predictors for lake water nitrogen concentrations (Zhu et al., 2008). Since these data were not available in our study area, we focused on relationships between vegetation, DOC concentrations and export rates. It has been shown that the hydrologic conditions and soluble carbon contents are the most important factors influencing the DOC production within a catchment (Neff and Asner, 2001). In this study, samples were collected during days where conditions would not be influenced by storm events, and thus DOC concentrations could be attributed to typical organic carbon contents within the catchment. Because large rivers usually have mixed land cover types with great heterogeneity in SOC contents, the direct comparisons of DOC concentrations among different land cover areas are scarce (Laudon et al., 2011; O'Donnell et al., 2016). In the permafrost region on the QTP, both the SOC and water extractable carbon contents are closely associated with land cover types (i.e., the wet meadow has highest SOC and water extractable organic carbon, and steppe and desert have the lowest values) (Hu et al., 2014; Wu et al., 2014; Shang et al., 2016). It has been also suggested that the land cover types are closely associated with the soil parameters such as taxonomy and texture on the QTP. In this study, the distribution of land cover types showed significant relationships with the $SUVA_{254}$ values. The $SUVA_{254}$ is a good indicator for the aromatic content in DOC. Although the aromatic materials are important for microbial growth, several reports suggest that higher $SUVA_{254}$ indicates lower bioavailable DOC (Mcdowell et al., 2006). An increase in $SUVA_{254}$ was recorded in an incubation experiment, as the microbes selectively degrade the more labile DOC components leaving the more recalcitrant and aromatic DOC compounds behind (Kalbitz et al., 2003; Pinsonneault et al., 2016). In the northern QTP, the $SUVA_{254}$ was a strong predictor for the bioavailable DOC (Mu et al., 2017). Therefore, the negative relationship between DOC concentrations and $SUVA_{254}$ suggested that the water with high DOC concentration has experienced low DOC degradation. Our results suggested that the rivers from wet meadow and meadow have higher biodegradable DOC than those from steppe and desert. The significant linear regressions for the DOC concentrations using land cover type distribution indicate the effects of SOC on the riverine DOC concentrations in the catchment.

Discharge rate and catchment area are also correlated with DOC concentrations and $SUVA_{254}$. The catchment area did not significantly correlate with discharge rates, indicating the complexity of catchment hydrological processes. In circum-arctic streams, although the DOC concentrations decreased with increasing catchment areas, it is difficult to draw conclusions about the DOC concentrations and catchment area because the catchments were covered by peatland and forest (Laudon et al., 2011). The multiple linear regressions showed that discharge and catchment areas are the best predictors for the DOC concentration, which confirmed that land cover type was not the only determinant for DOC concentration. The effects of catchment area and discharge could be explained by the decomposition processes of DOC during transport. The controlling factors for water chemistry and DOC concentrations in large catchments are much more complicated than small catchments. The discharge partly reflects the area of catchment, and larger discharges usually mean longer water residence time (Skop, 2013). The DOC in permafrost regions has a high proportion of biodegradable DOC, which can be rapidly mineralized to the atmosphere (Drake et al., 2015). In our study, the increasing aromaticity with discharge and catchment area supports this claim. The best model using multiple regressions clearly demonstrated that the most important factors affecting the aromaticity were discharge, together with the land cover type. The model explained 93.6% of the total $SUVA_{254}$ variances.

We calculated the DOC export rates based on the data collected from a single measurement during the summer. Since there are typically seasonal variations in both DOC concentrations and discharges (Mu et al., 2017), our results could not be used to upscale to annual export rates for the catchments. Future studies are required to understand the seasonal changes in the DOC concentrations, biodegradability and export rates among different catchments in permafrost regions.

Samples were collected during same periods, and thus it was possible to compare the differences in the DOC export rates among the catchments. In our study, the DOC export rate positively correlated with discharge, which is not surprising since the export of water is a major variable in the calculation. However, this is contrary to the relationship between DOC concentration and discharge where DOC could be diluted by additional water, suggesting greater export of DOC with increasing discharge despite the inverse relationship with DOC concentration. Although the evaluation of annual transport of DOC requires sampling throughout the year, our results highlight the importance of hydrological processes in the catchment. The mechanisms of the DOC export in the catchments may be very complicated. For example, the soils under meadow and wet meadow usually have finer soil particles, higher vegetation cover and biomass (Li et al., 2014; Wu et al., 2017), which can reduce runoff (Puigdefábregas, 2010). Additionally, the soils under steppe and desert have coarse soil particles, and thus have lower stabilization and adsorption of organic carbon (Six et al., 2000), which may lead to higher export rates of DOC in these catchments.

Permafrost on the QTP is sensitive to global warming because of the relatively high ground temperature. In many areas, the ground temperature is only slightly below the freezing point (Zhao et al., 2010), and thus a one-degree temperature increase would cause great changes to the permafrost on the QTP. Unlike the circum-arctic areas, where thawing ground ice can provide more soil water for plant growth (Jorgenson et al., 2001; Lupascu et al., 2014), the deepening active

layer in the QTP usually decreases the soil water content (Wu et al., 2017). It has been suggested that permafrost degradation on the QTP will lead to vegetation degradation, and shift the land cover from meadow to steppe and desert (Yang et al., 2004; Yang et al., 2010). Based on the assumption that future precipitation is similar to present, our results suggested that a shift from meadow and wet meadow to steppe under future global warming could decrease the riverine DOC concentrations. This would also increase DOC export rates because the land cover change would lead to an increase in discharge. During the riverine transport, part of the DOC can be rapidly mineralized to atmosphere. In addition, the global warming will degrade the vegetation, and thus increase the TSS export in the rivers (i.e., accelerate the soil erosion processes in the permafrost regions).

5. Conclusions

By examining water quality parameters, DOC concentration, $SUVA_{254}$ values, and discharge in the catchment under typical land cover types in the eastern QTP, we found TSS, DOC concentrations, and optical properties were associated with catchment area, land cover type, and discharges rates. Our results showed that TSS concentrations in the rivers were lowest when the catchment was meadow and wet meadow, while highest under steppe and desert. The significant relationships among these variables demonstrated that land cover type is an important factor affecting the DOC concentrations, as well as DOC decomposability in the permafrost region. The DOC transport rates were affected by discharge with the higher discharge rates being associated with higher DOC export in the catchment. The $SUVA_{254}$ was lower in the rivers under meadow and wet meadow, but higher in rivers with greater discharge. Our results show that the overall DOC transport and its decomposability depended on the catchment area, land cover type distribution and discharge rate. If global warming causes degradation of vegetation on the QTP, then the soil erosion processes will be accelerated. The DOC concentrations in the rivers would decrease while the DOC export rates would increase. Meanwhile, some of the exported DOC will be rapidly mineralized to the atmosphere, and potentially affect the regional carbon cycle on the QTP.

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